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RESEARCH FOR THE TREATMENT OF ORGANICS
IN DRINKING WATER

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RESEARCH FOR THE TREATMENT OF ORGANICS IN DRINKING WATER

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The past ten years may perhaps be described as the beginning of our understanding of the topic of trace organics in drinking water. General organic quality measurements such as color, oxidant demand and tastes and odors have given way to more sophisticated and improved analytical procedures such as total organic carbon (TOC), total organic halogens (TOX), and a seemingly endless list of specific organic compounds. Most notable among the latter are the trihalomethanes (THM), a group of compounds that are secondary effects of chlorination, and a plethora of industrial solvents such as tri- and tetrachloroethylene now being detected in some ground water. Just as no single analytical technique exists to measure all organics, no single treatment process exists for controlling them in drinking water.

The Three-Tiered Approach to Research

The U. S. Environmental Protection Agency, Drinking Water Research Division's (EPA-DWRD) "client" is the U.S. EPA Office of Drinking Water, which is required by the Safe Drinking Water Act to assess treatment, along with occurrence, analytics, and health effects before considering a regulation. EPA-DWRD uses a three-tiered approach to gather data on the treatment alternatives that may be cost effective without substituting the organic problem for microbiological or inorganic deterioration, enhanced corrosion, or degradation of the surrounding environment.

The first step is bench-scale, where the chemical behavior of the organic contaminant can be investigated in a closely controlled environment. The next level, pilot-scale, is an attempt to match the contaminant with an effective treatment process. This might require modifying an existing water treatment technique or exploring the feasibility of adopting a process being used for some other purpose. The final step is to take the most promising treatment ideas to the field for full-scale evaluation (examine operational problems and costs) at one or more sites with waters having the organic contaminant(s) of concern.

This sequential approach to treatment research is being used on EPA-DWRD's three highest priority organic issues: volatile organic compounds (VOCs), synthetic organic compounds (SOCs), and

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disinfection by-products, (TOX and "problem" THM waters). The first two steps, bench- and pilot- scale, are generally done in-house at the Andrew W. Breidenbach Environmental Research Center in Cincinnati, Ohio. The best example of the success of the three-tiered approach is the topic of disinfection by-products, namely the trihalomethanes. After bench-scale experimentation on THMs in the mid-1970s (1) pilot- and full-scale work followed (2), and subsequently a regulation was promulgated (3). Volatile organic compounds (4) and synthetic organic compounds (5) are now the contaminants being studied. Microgram per liter (ug/L) concentrations of these compounds are subjected to a bench- and pilot-scale treatment protocol consisting of oxidation, adsorption, reverse osmosis, aeration, and conventional treatment.

EPA-DWRD has two pilot-scale conventional water treatment plants for studying treatment of trace organics. To the extent possible, both are constructed of stainless steel, Teflon[®] and glass to minimize adsorption/desorption of contaminants during study. One plant is housed in a trailer so it can be trucked to a study site. It is comprised of two, 2 gal/min (gpm) (7 L/min) units, each consisting of rapid mix, stepped paddle flocculation, sedimentation, filtration, and finished water storage. The units can be run in series or parallel. This plant is currently in Florida, where it is being operated in parallel with a full-scale plant to investigate disinfection by-product control. At that location the pilot plant has consistently produced water with a turbidity, TOC, and THM formation potential within 10 percent of the concentrations produced in the full-scale plant. The other plant, housed at EPA in Cincinnati, is similar to the trailer mounted unit.

Comparing Full-Scale and Pilot-Scale Treatment Performance

The ability to predict full-scale performance from pilot systems provides utilities with an economical screening mechanism before making decisions relative to treatment change. If pilot systems are to be used for this function, the basic question is their reliability in predicting full-scale performance. In some studies, EPA-DWRD pilot plants are not used; rather, on-site pilot facilities are utilized. Some examples follow.

During a research study at Evansville, Indiana, a 100 gpm (0.4 m³/min) pilot plant (Neptune Microfloc Waterboy) was compared to a 30 million gallons/day (MGD) (79 m³/min) full-scale plant. The two plants were operated similarly. One difference, however, was the addition of an anionic, high molecular weight flocculant aid to the pilot plant to achieve acceptable turbidity removal. Pilot plant detention time was 2-hours compared to 5-hours detention time in the full-scale plant. Despite these differences, the quality of the effluents was similar (6).

In Cincinnati, Ohio (7), pilot scale adsorbers containing granular activated carbon (GAC) were evaluated vis-a-vis full-size

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units. The 3-in (7.5 cm) diameter by 30-in (75 cm) deep columns had approximately the same hydraulic loading applied as the full-scale system [7.6 gal/min/ft² (19 m/hr) for the pilot adsorber and 7.4 gpm (18 m/hr) for the full-scale adsorber], giving empty bed contact times of 14.8 and 15.3 min., respectively. The pilot system predicted the full-scale adsorber performance within 10 percent for the 7-month study (Figure 1).

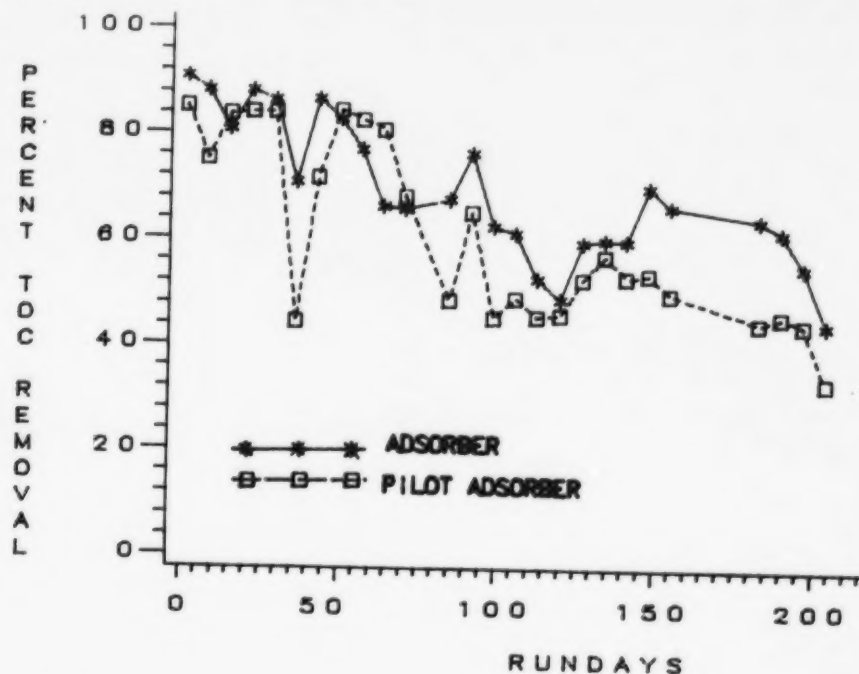


FIGURE 1. Pilot- vs. Full-Scale GAC Adsorption of TOC, Cincinnati, OH

At Jefferson Parish, Louisiana (8), the pilot-scale adsorbers closely replicated the full-scale system performance. As in the Cincinnati study, controlling flows, so each system had an identical loading, was difficult.

Estimating Costs Based on Pilot Plant and Full Scale Data

Treatment costs can be estimated from performance and design data collected from bench, pilot and full scale research activities. These costs can be used to rank logical treatment processes for future research, to evaluate the sensitivity of various designs to changes, and to make final selections for construction of full scale treatment systems. The following is one means of classifying cost estimates:

1. Order of magnitude estimates;
2. Study estimates that may result from pilot plant data and general cost curves;

3. Preliminary estimates that require the individual and independent estimation of each item to be considered in the cost analyses;
4. Detailed estimates that call for detailed information from an engineering design and are costly to prepare;
5. Definitive estimates that are used to control the cost of the project being built and are for site specific installations.

At each level, the knowledge of the cost associated with a given project becomes more accurate. To illustrate how cost estimates can evolve, an experience with granular activated carbon full-scale studies in Cincinnati, Ohio is presented. In this project (7), pilot- and bench-scale studies were used to predict the performance and costs associated with a 2 MGD (5 m³/min) capacity granular activated carbon adsorption system with fluidized bed reactivation. Table 1 illustrates the cost estimates made from the bench- and pilot-scale versus the actual constructed cost as experienced from the full scale operation.

TABLE 1. COST COMPARISON BETWEEN EXPERIENCED AND PREDICTED COSTS

Item	Experienced	Estimated (Preliminary Estimate #3)
Total Capital, \$	2,053,140	1,900,000
Contactor O&M, \$/yr	35,570	45,581
Fluidized Bed Reactivation O&M, \$/yr	190,310	72,600

As can be seen in Table 1, the estimated fluidized bed reactivation O&M costs were different by a factor of 2 from the actual or experienced cost. This discrepancy was the result of underestimating the maintenance and repair costs and the operating labor anticipated for the reactivation furnace, because fluidized bed technology was relatively new for carbon reactivation. This experience is being utilized in predicting costs for other full-scale operations.

Another example of the increased understanding that comes with experience is the assignment of operating labor for full-scale application. The utility involved in this study assigned one operator per shift to monitor reactivation for its full-scale plant. The utility found, however, that one operator can monitor a 12,000 lb per day furnace as easily as a 50,000 lb per day furnace, so significant economies of scale are associated with furnace operating labor. Therefore, as the system is scaled up the number of operators will stay constant. This example illustrates the need for experience and judgment when applying cost estimating technologies to full-scale operation.

On-Going Research Projects

EPA-DWRD has funded several research projects that will provide treatment data from both pilot- and full-scale units. These projects are primarily at locations having either pesticides or industrial solvents in the ground water. A summary of these activities are shown in Table 2.

TABLE 2. USEPA-DWRD PROJECTS USING BOTH PILOT- AND FULL-SCALE UNITS FOR TREATMENT RESEARCH ON ORGANICS

Location	Organic Contaminant(s)	Project Dates	Objective
Brewster, NY	Industrial Solvents	1982-1985	To see how reliable a small-scale aeration column predicts full-scale performance.
Baldwin Park, CA	Industrial Solvents	1983-1985	To evaluate the secondary effects of aeration (e.g., off-gas dispersion, corrosion, etc.)
Daytona Beach, FL	Disinfection By-Products	1983-1984	To evaluate a polymeric coagulant for THM control.
Wausau, WI	Industrial Solvents, precursors, TOC	1983-1986	To compare GAC design based on adsorption isotherm and mathematical modeling with pilot-scale data. Also, to compare pilot-scale air-stripping and GAC with full-scale unit.
Suffolk Co., NY	Pesticides	1983-1987	Bench-scale resin and GAC adsorption, and reverse osmosis to predict point-of-use and centralized treatment.
Thornton, CO	Disinfection By-Products, Nitrogenous Compounds	1981-1984	To develop a treatment process to control THMs without producing NO ₂ and NO ₃ in distribution system.

Future Research

Bench and pilot scale experimentation followed by full-scale evaluation has been successful, but it does take considerable time to conduct a thorough assessment of a problem organic. For that reason, EPA-DWRD is now placing greater emphasis on two areas. The first is developing the relationships between chemical/molecular characteristics of the organics and the effectiveness of different treatment processes. This will allow the engineer to speculate on what process or combination of processes might be needed for a particular quality of water and ultimately may minimize the need for extensive pilot-scale experimentation. Secondly, more emphasis is being placed on relating the costs of treatment to the overall changes in drinking water quality.

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